



# *Cervical Resistance Training: Effects on Isometric and Dynamic Strength*


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# Cervical Resistance Training: Effects on Isometric and Dynamic Strength

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***Introduction:*** Neck injuries signify a physical fitness and human system problem with high operational significance. The prevalence of injuries in tactical aviators has been reported to be as high as 84%, although few report engaging in neck-specific strengthening exercises. It is generally believed that neck strengthening may result in fewer neck injuries. This study was designed to investigate the effects of 12 wk of cervical strength training (3 $d \cdot wk^{-1}$) on isometric strength, dynamic strength, and hypertrophy in a sample of military men. ***Methods:*** Participants were tested for each of the above-mentioned variables before and after the training program as well as at 4-wk intervals, and results were compared with a control group that performed no cervical resistance training. ***Results:*** Results indicated significant improvements in isometric strength and dynamic strength, typically occurring as early as 4 wk and improving throughout the 12-wk period. Modest increases in neck circumference were also noted. ***Discussion:*** These findings have implications for military personnel at risk of neck injury in their occupational activities.

**Keywords:** neck strength, resistance training.



NECK INJURIES signify a physical fitness and human system problem with high operational significance. For example, in a survey of 52 fighter pilots, 44 (84.0%) reported having had a neck injury, 20 of whom reported their neck injury as having interfered with mission completion (7). In another survey of 437 pilots of high-performance aircraft (11), 50.6% reported acute neck injury within the preceding 3 mo. Similarly, a survey of 268 U.S. Air Force F-16 pilots (1) demonstrated a 1-yr prevalence of 56.6%, and 85.4% for an F-16 career. Furthermore, only 26.9% of the pilots routinely performed exercises. Improvements in neck strength as a result of dynamic strength training, though, have been associated with fewer sick leaves and G-force restrictions (10). Additionally, a recent comprehensive technical report from NATO's Research and Technology Organization on cervical spine injury associated with exposure to sustained acceleration recommended improvements in neck strengthening programs in an attempt to reduce injuries (3).

Several studies have investigated the link between cervical resistance training and strength outcomes. Conley et al. (4), for instance, found that subjects who performed head extension exercises in addition to other resistance training exercises (parallel squat, push press, bench press, crunch, Romanian dead lift, and bent rows) increased dynamic strength [3 × 10 repetitions maximum (RM)] by 33.0% compared with controls and subjects who performed only other types of resistance training, both of which resulted in no cervical strength changes. Furthermore, in a study by Leggett and colleagues (5), subjects increased their isometric cervical extension strength by 6.3% to 14.3% at 6 of 8 angles after performing 1 set (8 to 12 repetitions) of variable resistance cervical extensions 1 $d \cdot wk^{-1}$ for 10 wk. Comparatively, Pollock et al. (8) found greater increases of 8.6% to 42.1% in isometric cervical extension strength compared with controls. Additionally, Portero and associates (9) demonstrated significant increases in isometric strength for both right and left lateral neck flexion after 8 wk of training. To our knowledge, no previous work has investigated the effects of cervical resistance training on both isometric and dynamic strength relative to four primary directions of movement.

Although substantial literature has addressed the effects of resistance training on the hypertrophy of muscle, few studies have specifically examined hypertrophy of cervical musculature after resistance training. In a study by Conley et al. (4), total neck muscle cross-sectional area increased 13.0% when subjects performed head extension exercises in addition to other resistance exercises for 12 wk. Additionally, Portero et al. (9) found a significant increase in size of sternocleidomastoid and trapezius muscles after an 8-wk period of isometric strength training. As in the case of dynamic and isometric strength, to our knowledge, no previous research has examined hypertrophy changes as a result of strength training across all four directions of movement.

The present study was initiated to investigate the effects of 12 wk of cervical resistance training (three

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sessions per week) on isometric strength, dynamic strength, and neck circumference in a sample of military men. It was hypothesized that the resistance training intervention would result in significant increases in isometric strength. In the absence of control data for dynamic strength testing, this component of the study was observational. Congruent with the established resistance training literature (6), it was expected that strength gains would occur early in the intervention (4–8 wk), while hypertrophy changes would emerge later (8–12 wk).

## METHODS

The sample consisted of 10 men recruited from a Navy command in San Diego, CA. Five participants were assigned to the resistance training intervention, and five participants were assigned to the control condition. Although most of the participants engaged in weekly resistance training, none of the participants had engaged in any neck-specific exercises for at least 1 yr, and the control participants were asked to abstain from neck training throughout the 12-wk study. The Institutional Review Board of the Naval Health Research Center approved the study, and all volunteers were informed of their rights as human subjects prior to participation. Additionally, all volunteers completed a medical history questionnaire, which was used to identify anyone with a prior history of cervical problems or for whom exercise might have been contraindicated. Once medically cleared, volunteers were assigned to a cervical resistance-training group (RT) or a control group (C).



### *Endpoints*

*Isometric strength:* Isometric strength values were obtained for flexion, extension, and left and right lateral flexion using the Hanoun Multi-Cervical Unit (MCU; Hanoun Medical, Inc., Greenwood Village, CO). Volunteers were secured in the seat with a lap belt and shoulder straps to minimize torso movement and were instructed to cross their arms across the chest. They were instructed to push maximally against a fixed load cell for four trials, for 3 s per trial. Before data collection began, volunteers were asked to push against the load cell with a submaximal effort in order to familiarize themselves with the movement. The MCU calculated the average of the final 2.5 s of the 3-s trial, and the first 0.5 s was discarded to control for individual differences in time to reach maximal isometric force. A 10-s rest period was given between trials. For each direction, the first of the four trials was uniformly discarded and retested. The MCU calculated a coefficient of variation (CoV) for the three trials, and coefficients of 10.0% or less were considered acceptable. If unacceptable CoVs were produced, outlying trials were discarded and retested until an acceptable value was achieved. Average CoVs at baseline were 5.0% (flexion), 4.4% (extension), 4.5% (left lateral flexion), and 5.2% (right lateral flexion). The MCU also calculated the mean.

*Dynamic strength:* Dynamic strength was measured using 10 RM, with each participant lifting the maximum amount of weight for 10 consecutive repetitions at a minimum of 75.0% of maximum range of motion [ROM; observed by the ROM indicator on the Hanoun MCU, and in all four directions (flexion, extension, and right and left lateral flexion]. Weight was progressively overloaded during initial training sessions until 10 RM was achieved. Baseline 10 RM was achieved within the first five training sessions for all participants.

*Neck circumference:* At baseline and weeks 4, 8, and 12, neck circumference measurements were taken and two measurements were taken for each site. Standardized procedures were followed (2). Specifically, the participant was instructed to look "straight ahead" so that the head was in a neutral position. A measuring tape was then placed around the neck, just below the larynx. All measures were taken in the horizontal plane (i.e., parallel to the floor), and the tape measure was applied to the body with sufficient tension to keep it in place following the contour of the body without indenting skin surfaces. To promote reliability, the same researcher was assigned to measure a given participant at all four time points. Two measurements were taken for each site. If measurements differed by more than 0.4 cm, a third measurement was obtained and the outlying measurement was discarded. Measurements then were averaged.

### *Procedure*

All participants were measured for height, weight, neck circumference, isometric strength, and body fat content (DXA-predicted) at weeks 1 and 12. The RT group was also tested for these variables at weeks 4 and 8, as well as dynamic strength (10 RM) at baseline (achieved during the first five training sessions), 4, 8, and 12 wk. Isometric strength tests did not replace training sessions, but were performed prior to them on scheduled testing days.

*Training protocol:* The RT group participated in dynamic neck strengthening exercises on the MCU (including flexion, extension, and right and left lateral flexion) three times per week for 12 wk. Volunteers were fixed in the MCU as they were for the isometric testing. For each exercise, volunteers completed a warm-up set followed by 3 sets of 10 repetitions maximum ($3 \times 10$ RM) with a 90-s rest period given between sets. Total workout time was approximately 40 min per session. Based on initial pilot work correlating isometric 1-RM to dynamic 10-RM weights, the initial exercise weights were assigned based on the results of the isometric tests: warm-up weights were set at 20.0% of maximum isometric force, and the exercise weights were set at 45.0% for flexion and for right and left lateral flexion, and 75.0% for extension. Maximal ROM for each direction was determined during an initial warm-up set using a ROM indicator located on the MCU. Subsequently, participants were instructed to maintain at least 75.0% of their maximal ROM for every repetition performed. Also, participants were instructed and encouraged to maintain a rhythmic cadence (approximately 2 s for concentric and eccentric movements, respectively), and to avoid resting between repetitions. Participants were given several opportuni-

TABLE I. RESISTANCE TRAINING VS. CONTROL GROUPS: ISOMETRIC STRENGTH (LB).

| | RT Group (n = 5) | | | | C Group (n = 5) | | | |
|---|---|---|---|---|---|---|---|---|
| | FLX | EXT | RLF | LLF | FLX | EXT | RLF | LLF |
| Baseline | 29.4 (4.5) | 41.2 (9.0) | 28.7 (6.0) | 30.2 (6.2) | 26.5 (2.4) | 40.9 (9.0) | 32.0 (6.1) | 32.7 (7.3) |
| Wk 4 | 39.2 (7.4)* | 60.5 (5.6)* | 44.0 (3.3)$^{\dagger}$ | 46.6 (3.6)$^{\dagger}$ | - | - | - | - |
| Wk 8 | 38.6 (6.2)* | 66.5 (10.1)* | 49.5 (4.8)$^{\dagger}$ | 50.6 (3.6)$^{\dagger}$ | - | - | - | - |
| Wk 12 | 43.0 (11.7) | 71.0 (14.7)* | 52.4 (9.0)* | 51.9 (6.7)$^{\dagger}$ | 27.8 (4.0) | 43.6 (11.5) | 32.1 (4.0) | 34.5 (7.5) |

RT = resistance training, C = control, FLX = flexion, EXT = extension, RLF = right lateral flexion, LLF = left lateral flexion, LSD = least significant difference; no significant group (RT vs. C) differences at baseline for any direction of movement.
* Significantly different from baseline (LSD pairwise comparison) ($p < 0.05$).
$^{\dagger}$ Significantly different from baseline (LSD pairwise comparison) ($p < 0.01$).

ties to practice proper ROM and cadence during an initial familiarization session, and both ROM (via the MCU ROM indicator) and cadence were monitored at all times during the training sessions by an American College of Sports Medicine certified member of the research staff. If the volunteer could perform 12 consecutive repetitions, weight was increased by 1 unit on the weight stack (1–2.5 lb) as necessary to maintain the 10 RM for subsequently performed sets.

### *Data Analysis*

Analyses included descriptive statistics, multivariate analysis of variance (MANOVA), analysis of variance (ANOVA) with repeated measures and post hoc comparisons (least significant differences). Descriptive statistics were used to summarize the physical and demographic characteristics of the sample. MANOVA was used to test for group differences in key demographic variables (age, height, weight, DXA-measured body fat, neck circumference) at baseline. ANOVAs with repeated measures were performed to explore dynamic strength changes in RT throughout the training period and 2 (group) × 2 (time) ANOVAs with repeated measures were performed to assess pre/post training effects in isometric strength.



## RESULTS

### *Characteristics of the Sample*

Mean age, height, weight, body fat content, and neck circumference of this sample were 38.6 yr (SD = 6.7), 174.2 cm (SD = 8.7), 81.5 kg (SD = 12.2), 23.0% (SD = 8.2), and 38.5 cm (SD = 2.1), respectively. MANOVA demonstrated that participants assigned to the RT and C groups did not differ significantly on these variables ($F = 2.7$, $p = 0.16$). Participants assigned to the RT protocol demonstrated good adherence to the training protocol (M = 85.0%, SD = 9.4%).

### *Experimental vs. Control Group: Isometric Strength, Dynamic Strength, and Neck Circumference*

Isometric strength values are displayed in **Table I**. For isometric strength-flexion, the 2 × 2 ANOVA indicated substantial pre/post improvements in RT but not in their untrained counterparts (interaction effect: $F = 3.5$, $p < 0.10$, observed power = 0.38). Also, the ANOVA with repeated measures examining all four time points for the resistance-trained participants was significant ($F = 4.6$, $p < 0.05$, observed power = 0.76), and post hoc comparisons [least significant difference (LSD)] specified significant improvements from baseline after 4 wk of training (+32.7%, $p < 0.05$), 8 wk (+31.1%, $p < 0.05$), and marginally significant improvements at 12 wk (+45.9%, $p < 0.10$).

Relative to isometric strength-extension, the 2 × 2 ANOVA indicated significant pre/post improvements in RT but not C (interaction effect: $F = 6.0$, $p < 0.05$, observed power = 0.58). The ANOVA with repeated measures examining all four time points for RT was also significant ($F = 7.6$, $p < 0.01$, observed power = 0.94), with post hoc comparisons (LSD) further demonstrating significant differences after 4 wk (+46.8%, $p < 0.05$), 8 wk (+61.3%, $p < 0.05$), and 12 wk of training (+72.1%, $p < 0.05$). Similarly, the 2 × 2 ANOVA with repeated measures on isometric strength-right lateral flexion indicated significant pre/post improvements in RT but not C (interaction effect: $F = 11.6$, $p < 0.01$, observed power = 0.85). The ANOVA with repeated measures on all four time points for RT was also significant ($F = 14.6$, $p < 0.001$, observed power = 0.99) in the resistance-trained participants relative to isometric strength-right lateral flexion and post hoc comparisons (LSD) pinpointed significant differences from baseline at 4 wk (+53.7%, $p < 0.01$), 8 wk (+72.6%, $p < 0.01$), and 12 wk (+83.0%, $p < 0.05$). Relative to isometric strength-left lateral flexion, significant improvements were shown in the RT group but not the C group (interaction effect: $F = 11.7$, $p < 0.01$, observed power = 0.85). The ANOVA with repeated measures on all four time points for RT was also significant ($F = 18.2$, $p < 0.01$, observed power = 0.97), and post hoc comparisons (LSD) further delineated significant differences from baseline at 4 wk (+54.4%, $p < 0.01$), 8 wk (+67.4%, $p < 0.01$), and 12 wk (+71.8%, $p < 0.01$).

Dynamic strength (10 RM) values for RT are shown in **Fig. 1**. Relative to dynamic strength-flexion, an ANOVA with repeated measures yielded an overall training effect ($F = 12.8$, $p < 0.01$, observed power = 0.96) and post hoc comparisons (LSD) further demonstrated significant differences from baseline at 8 wk (+39.2%, $p < 0.01$) and 12 wk (+49.3%, $p < 0.01$). An overall training effect was also demonstrated in the resistance-trained participants relative to dynamic strength-extension ($F = 8.0$, $p < 0.01$, observed power = 0.95), and post hoc comparisons (LSD) specified significant differences at 4 wk (+17.9%, $p < 0.05$), 8 wk (28.1%, $p < 0.05$), and 12 wk (36.6%, $p < 0.05$). Also, a main effect was observed

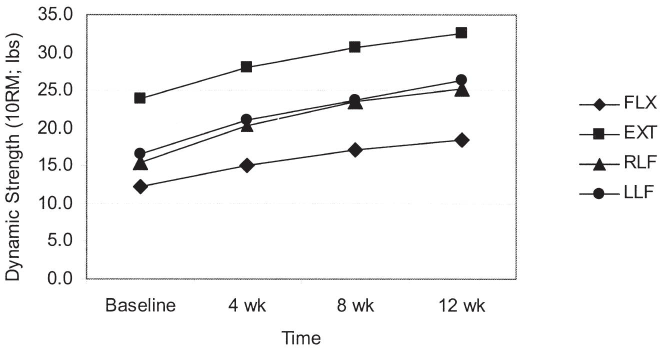


**Fig. 1.** Dynamic strength changes in the RT group. FLX = flexion, EXT = extension, RLF = right lateral flexion, LLF = left lateral flexion.

($F = 11.8$, $p < 0.001$, observed power = 0.99) in the resistance-trained participants relative to dynamic strength-right lateral flexion, and post hoc comparisons (LSD) further demonstrated significant differences after 4 wk (+31.6%, $p < 0.05$), 8 wk (+51.3%, $p < 0.01$), and 12 wk (+63.1%, $p < 0.01$). Finally, an overall effect was observed ($F = 8.2$, $p < 0.01$, observed power = 0.64) in the resistance-trained participants relative to dynamic strength-left lateral flexion, and post hoc comparisons (LSD) further demonstrated significant differences at 4 wk (+27.2%, $p < 0.05$), 8 wk (+43.3%, $p < 0.01$), and 12 wk (+59.4%, $p < 0.01$)

Mean neck circumference in RT changed from 38.8 cm at baseline (SD = 3.1) to 40.2 cm after 12 wk of dynamic resistance training, suggesting possible neck hypertrophy adaptations to resistance training. No appreciable pre/post changes in neck circumference were observed in C. Unfortunately, the 2 × 2 ANOVA lack sufficient statistical power to allow meaningful interpretation (interaction effect: $F = 2.8$, $p = 0.14$, observed power = 0.31).

## DISCUSSION

The purpose of this study was to examine the effects of 12 wk of cervical resistance training (three sessions per week) on isometric strength, dynamic strength, and neck circumference in a sample of military men. The prescribed cervical strength-training program resulted in significant increases in both isometric and dynamic strength. As expected, improvements in both endpoints were achieved early in the intervention, and either maintained or enhanced with continued training. Finally, a modest increase in neck circumference was observed after 12 wk of training. These findings have implications for military personnel at risk of neck fatigue, strain, and injury in their occupational endeavors.

The training program yielded significant increases in isometric strength in the RT group but not the control group. Substantial increases in dynamic strength were also observed in the RT group, while the control group did not perform dynamic testing. Resistance-trained participants increased dynamic extension strength by 36.6% after 12 wk of training. This is similar to the 33.0% increase in the 3 × 10 RM for neck extension observed by Conley et al. (4). Our observed improvements in isometric strength exceed those found by Portero et al. (9), which can best be attributed to different characteristics of the training programs. Specifically, these researchers found a 35.0% increase in lateral flexion isometric strength after 8 wk of isometric training (1 set of 10 contractions), while we have demonstrated a 72.6% increase in right lateral flexion isometric strength and a 62.4% increase in left lateral flexion isometric strength after 8 wk of dynamic training, as well as further increases after an additional 4 wk.

We observed dramatic increases in isometric cervical extension strength (72.1%) which were dramatically larger than the 6.3% to 14.3% demonstrated by Leggett and colleagues (5). This difference may be due to the difference in training programs. In particular, the subjects in the latter study performed 1 set of 8 to 12 cervical extensions 1 $d \cdot wk^{-1}$ for 10 wk, while subjects in the present study performed 3 sets of 10 repetitions 3 $d \cdot wk^{-1}$ for 12 wk.

### *Limitations and Future Research Directions*

This study does have some limitations. To begin, participants were not randomized to experimental and control groups. Rather, they were selected and assigned to conditions based on their ability to commit to the training program. Several participants, for instance, had heavy travel schedules and could only commit to baseline and end-of-study testing, which resulted in their assignment to the control group. Despite this limitation, experimental and control group participants did not differ on any of the key physical characteristics (age, height, weight, body fat, neck circumference), or baseline isometric strength. Another limitation concerns the fact that the RT and C groups were not compared relative to dynamic strength either at baseline or end of training. This decision was made because establishment of a credible approximation of maximal strength requires several training sessions to reach asymptotic strength values, particularly when the skill is not well learned. Isometric movements are less reliant on coordinated movement, and are thus less sensitive to this limitation. As noted earlier, 10 RM was achieved within the first five training sessions for all RT participants. For experimental integrity, control participants were asked not to participate in any neck-specific training throughout the course of the study, and we were concerned that dynamic strength training sessions prior to baseline and/or end of study isometric testing would confound the isometric strength measures for control participants. A further limitation concerns the fact that we did not collect strength data from the control participants at weeks 4 and 8, which would have enhanced validity for comparison purposes.

Given the time constraints placed on military personnel, it is important to identify the minimal amount of investment required to produce sufficient training adaptations. In the present study, participants performed neck exercises three times per week, and the training sessions consisted of three sets for each of four movements (flexion, extension, and right and left lateral flexion), resulting in a time investment of approximately 40 min per session. In light of this, future research is needed to determine if less training volume (i.e., fewer

training sessions, sets, and repetitions) can produce comparable results to those identified in the present study. In simple terms, it is important to ask the question, "Can we achieve the same (or more) with less?"

Additionally, although the MCU significantly improved neck performance in the present study, it is a relatively large and expensive piece of equipment. In light of this, it is important to compare its performance outcomes to more cost-effective modalities requiring substantially less equipment and training, and which can be easily implemented at the squadron or unit level. Examples of such cost effective methods include weighted-helmet training, hand-assisted self-resistance training (i.e., individual provides own resistance to neck movement), and hand-assisted "buddy" resistance training (i.e., training partner provides resistance to neck movement). More research, then, is needed to compare the MCU with alternative, more cost-effective training modalities.

Finally, although it is generally accepted that neck strength is related to prevalence and/or severity of neck injury, little research has been performed to substantiate the relationship (1,3,10). As noted earlier, a survey of F-16 pilots (1) demonstrated a 1-yr prevalence of 56.6%, and 85.4% for an F-16 career, while only 26.9% of the pilots routinely performed exercises. Improvements in neck strength as a result of dynamic strength training have also been associated with fewer sick leaves and G-force restrictions (10), and a recent comprehensive technical report on cervical spine injury associated with exposure to sustained acceleration recommended improvements in neck strengthening programs in an attempt to reduce injuries (3). Future research should evaluate the relationship between neck performance variables and subsequent injuries, and these studies should be prospective across a substantial time frame (at least 6 mo), use control groups, and employ random assignment where possible.



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**14. ABSTRACT (maximum 200 words)**

This study was designed to investigate the effects of 12 weeks of cervical strength training (3 days per week) on isometric strength, dynamic strength, and hypertrophy in a sample of military men. A second purpose was to examine how hypertrophy changes due to resistance training would affect the Department of Defense (DoD) circumference-based body fat estimation equation. Participants were tested for each of the above-mentioned variables before and after the training program as well as at 4-week intervals, and results were compared with a control group that performed no cervical resistance training. Results indicated significant improvements in isometric strength and dynamic strength, typically occurring as early as 4 weeks and improving throughout the 12-week period. After 12 weeks of training, marginally significant increases in neck circumference were demonstrated, which resulted in significant changes in estimated body fat. The findings regarding isometric and dynamic strength have implications for military personnel at risk of neck injury in their occupational activities. The neck circumference results could have an impact on organizations using the DoD estimation equations to assess the body composition of its members.

**15. SUBJECT TERMS**
neck strength, resistance training, body fat

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